CHAPTER 7 - RADIOLOGICAL DOSE ASSESSMENT

It is the policy of DOE ". . . to conduct its operations in an environmentally safe and sound manner. Protection of the environment and the public are responsibilities of paramount importance and concern to DOE" (DOE Order 5400.1). "It is also a DOE objective that potential exposures to members of the public be as far below the limits as is reasonably achievable. . ." (DOE Order 5400.5).

Chapter 4 of this report summarized the amount of radioactivity in air emissions and other media sampled in the WIPP environment in 2001. It is the purpose of this chapter to summarize the air emission levels in regard to the potential dose from WIPP operations.

Specifically, this chapter summarizes:

- Regulatory requirements on emissions of radionuclides, effective dose equivalents, and use of CAP88-PC computer model;
- The national average dose from naturally occurring sources of radiation;
- The estimated dose from air emissions from WIPP;
- The total potential dose from WIPP operations; and
- Potential doses to nonhuman biota from radioactivity measured near WIPP.

7.1 Introduction and Dose Limits

Title 40 CFR Part 61, Subpart H-National Emission Standards for Emissions of Radionuclides Other than Radon From Department of Energy Facilities, Section 61.92 Standard state "Emissions of radionuclides to the ambient air from Department of Energy facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/year."

Compliance with the above regulatory compliance is determine by measuring effluent flow rate, monitoring, extracting, collecting, and measuring radionuclides, and calculating the effective dose equivalent (EDE). The EDE is the weighted sum of the doses to the individual organs of the body. The dose to each organ is weighted according to the risk that dose represents. These organ doses are then added together, and that total is the effective dose equivalent. In this manner, the risk from different sources of radiation can be controlled by a single standard.

To calculate the EDE to members of the public, require the use of CAP88-PC or other EPA approved computer models and procedures. The WIPP Effluent Monitoring Program generally uses CAP88-PC. CAP88-PC is a set of computer programs, datasets and associated utility programs for estimation of dose and risk from radionuclide air emissions. CAP88-PC uses a Gaussian Plume dispersion model, which predicts air concentrations, deposition rates, concentrations in food, and intake rates for people. CAP88-PC estimates dose and risk to individuals and populations from multiple pathways. Dose and risk is calculated for ingestion, inhalation, ground level air immersion and ground surface irradiation exposure pathways.

Environmental radiation protection standards for the management and disposal of TRU wastes set limits on the total annual radiation dose to members of the public at 0.25 mSv (25 mrem) to the whole body and 0.75 mSv (75 mrem) to any critical organ (40 CFR §191.03). National standards for emissions of radionuclides from DOE facilities state that the maximum annual dose to any member of the public from air emissions must be no greater than 0.1 mSv (10 mrem) (40 CFR §61.92). The SDWA (40 CFR §141.16) states that average annual concentrations of beta- and gamma-emitting human-made radionuclides in drinking water shall not result in an annual dose greater than 0.04 mSv (4 mrem). It is important to note that all of these dose limits are set for radionuclides released to the environment from DOE operations. They do not include, but are limits in addition to, doses from natural background radiation or from medical procedures.

7.2 Background Radiation

Radiation is a naturally-occurring phenomenon that has been in the environment since the beginning of time. There are several sources of natural radiation: cosmic and cosmogenic radiation (from outer space and the earth's atmosphere), terrestrial radiation (from the earth's crust), and internal radiation (naturally-occurring radiation in our bodies, such as ^{40}K). The most common sources of terrestrial radiation are uranium, thorium, and their decay products. Potassium-40 is another source of terrestrial radiation. While not a major radiation source, ^{40}K may be enhanced in the southeastern New Mexico environment due to local potash mining. Radon gas, a decay product of uranium, is the most widely known naturally-occurring terrestrial radionuclide. In addition to natural radioactivity, small amounts of radioactivity from above-ground nuclear weapons tests that occurred from 1945 through 1980 and the 1986 Chernobyl nuclear accident are also present in the environment. Together, these sources of radiation are called "background" radiation. Every human is constantly exposed to background radiation. Exposure to radioactivity from weapons testing fallout is quite small compared to natural radioactivity and continually gets smaller as radionuclides decay.

Naturally occurring radiation in our environment can deliver both internal and external doses. Internal dose is received as a result of the intake of radionuclides. The major routes of intake of radionuclides for members of the public are ingestion and inhalation. Ingestion includes the intake of the radionuclides from eating and drinking contaminated food or drink. Inhalation includes the intake of radionuclides through breathing dust particles containing radioactive materials or radon gas. External dose can occur from submersion in contaminated air or deposition of contaminants on surfaces. The average annual dose received by a member of the public from naturally-occurring radionuclides is about 3 mSv (300 mrem) (Table 7.1).

Table 7.1 - Annual Estimated Average Radiation Dose Received by a Member of the Population of the United States from Naturally Occurring Radiation Sources (adapted from NCRP, 1987)

Source	Average Annual Effective Dose Equivalent (mSv)	(mrem)
Inhaled (Radon and Decay Products)	2	200
Internal Radionuclides	0.39	39
Terrestrial Radiation	0.28	28
Cosmic Radiation	0.27	27
Cosmogenic Radioactivity	0.01	1
Rounded Total from Natural Sources	3	300

7.3 Dose from Air Emissions

The NESHAP issued by the EPA set limits for radionuclide emissions to air (40 CFR Part 61). Compliance procedures for DOE facilities (40 CFR §61.93[a]) require the use of CAP88-PC or AIRDOS-PC computer models, or an equivalent, to calculate dose to members of the public. For the determination of the radiation dose received by members of the public, WIPP used the computer model CAP88-PC, version 2.0. Source term input for the program was determined by radiochemical analyses of periodic air samples taken from the effluent Stations A, B, and C (see Section 4.1). Air samples were analyzed for ^{241}Am, $^{239+240}$Pu, and ^{238}Pu because they constitute over 98 percent of the dose potential from contact-handled waste. Measured activity values greater than the MDC were used as a part of the source term for the air emission pathway and, for measured results less than the MDC, the MDC value was used as part of the source term (see Table 4.1). CAP88-PC dose calculations are based on the assumption that exposed persons remain at home during the entire year and all vegetables, milk, and meat consumed are home produced. Thus, this dose calculation is a maximum potential dose which encompasses dose from inhalation, submersion, deposition, and ingestion of air emitted radionuclides.

For 2001, the CAP88-PC model predicted the highest dose to someone residing near WIPP to be at the Smith Ranch approximately 8 km (5 mi) northwest of WIPP. Results showed the whole body dose potentially received by someone residing at this location to be about 4.96×10^{-8} mSv (4.96×10^{-6} mrem) per year.

7.4 Total Potential Dose from WIPP Operations

The radiation dose received by members of the public as a result of the management and storage of TRU radioactive wastes at any disposal facility operated by the DOE is regulated under 40 CFR Part 191, Subpart A. Specific standards state that the combined annual dose to any member of the public in the general environment shall not exceed 0.25 mSv (25 mrem) to the whole body and 0.75 mSv (75 mrem) to any critical organ. Section 7.3 discussed the potential dose received from radionuclides released to the air from WIPP. The following sections discuss the potential dose through other pathways and the total potential dose a member of the public may have received from WIPP operations during 2001.

7.4.1 Potential Dose from Water Ingestion Pathway

The potential dose to individuals from the ingestion of WIPP-related radionuclides transported in water is estimated to be nonexistent for several reasons. Drinking water for communities near WIPP comes from groundwater sources which are not expected to be affected by potential WIPP contaminants (based on current radionuclide transport scenarios summarized in the WIPP Safety Analysis Report (DOE/WIPP 95-2065). The only credible pathway for contaminants from WIPP to accessible groundwater is through the Culebra member of the Rustler Formation and the Dewey Lake Formation (DOE/CAO 96-2184). Water from the Culebra is naturally not potable due to high levels of TDS. Water from the Dewey Lake Formation is suitable for livestock consumption having TDS values below 10,000 mg/l. Groundwater and surface water samples collected around WIPP during 2001 did not contain radionuclide concentrations discernable from those in samples collected prior to WIPP receiving waste.

7.4.2 Potential Dose from Wild Game Ingestion

Game animals sampled during 2000 were mule deer, quail, rabbit, and fish. The only radionuclides detected were not different from background levels measured prior to commencement of waste shipments to WIPP. Therefore, no dose from WIPP-related radionuclides is estimated to have been received by any individual from this pathway during 2001.

7.4.3 Total Potential Dose from All Pathways

The only pathway for which a dose could be estimated was that of air emissions. Air emissions from WIPP were not above background ambient air levels. Estimated concentrations of radionuclides in air emissions accounted for the calculable dose from WIPP operations during 2001. The effective dose equivalent potentially received by the maximally exposed individual residing 8 km (5 mi) northwest of WIPP was calculated to be 4.96×10^{-8} mSv (4.96×10^{-6} mrem) per year whole body. This value is in compliance with the requirements of 0.1 mSv (10 mrem) per year as specified in 40 CFR §61.92.

In compliance with 40 CFR Part 191, Subpart A, the receptor selected resides year-round at the WIPP fence line located 350 meters in the NW sector. The dose to this receptor is estimated to be 8.99×10^{-7} mSv (8.99×10^{-5} mrem) per year whole body and 1.56×10^{-5} mSv (1.56×10^{-3} mrem) per year to the critical organ. These values are in compliance with the requirements of 0.25 mSv (25 mrem) and 0.75 mSv (75mrem) per year to the critical organ as specified in 40 CFR §191.03(b).

7.5 Dose to Nonhuman Biota

DOE Order 5400.5 lists the environmental radiation protection requirements that WIPP must meet to protect aquatic animals. In addition, dose limits below which no deleterious effects on populations of aquatic and terrestrial organisms have been observed have been discussed by the National Council on Radiation Protection and Measurements (NCRP-109) and the International Atomic Energy Agency (IAEA Technical Report Series No. 332). Those dose limits are:

- Aquatic animals - 10 mGy/d (1 rad/d)
- Terrestrial plants - 10 mGy/d (1 rad/d)
- Terrestrial animals - 1 mGy/d (0.1 rad/d)

The DOE has considered proposing these dose standards for aquatic and terrestrial biota under proposed rule 10 CFR Part 834, "Radiation protection of the public and the environment" but has delayed until guidance for demonstrating compliance was developed. The DOE-STD-XXXX-YR, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, was developed to meet this need. Although the proposed rule has not been implemented, the DOE requires reporting of radiation doses to non-human biota in the Annual Site Environmental Report using the Interim Technical Standard.

The Interim Technical Standard uses a multi-phase approach, including an initial screening phase with conservative assumptions. Software is provided with the Interim Technical Standard to conduct the screening evaluation. In the initial screen, Biota Concentration Guides (BCG) are derived using very conservative assumptions for a variety of generic organisms. Maximum concentrations of radionuclides detected in soil, sediment, and water during environmental monitoring are divided by the BCGs and the results are summed for each organism (DOE-STD-XXXX-YR). If the sum of these fractions is less than 1, the site is deemed to have passed the screen and no further action is required. This screening evaluation is intended to provide a very conservative evaluation of whether the site is in compliance with the recommended limits.

This guidance was used to screen radionuclide concentrations observed around WIPP during 2001 using the maximum radionuclide concentrations listed in Table 7.2. The sum of fractions was less than one for all media, demonstrating compliance with the proposed rule. Radiation in the environment surrounding WIPP does not have a deleterious effect on populations of plants and animals.

Table 7.2 - General Screening Results for Potential Radiation Dose to Nonhuman Biota from Radionuclide Concentrations in Surface Water (Bq/l), Sediment (Bq/g), and Soil (Bq/g) near the WIPP Site. Maximum detected concentrations were compared with BCG[a] values to assess potential dose to biota. As long as the sum of the ratios between observed maximum concentrations and the associated BCG is below 1.0, no adverse effects on plant or animal populations are expected (DOE-STD-XXXX-YR).

Medium	Radionuclide	Maximum Observed Concentration	BCG	Concentration/BCG
		Aquatic System Evaluation		
Sediment (Bq/g)	^{60}Co	6.85×10^{-4}	5.00×10^{1}	1.37×10^{-5}
	^{137}Cs	4.59×10^{-2}	1.00×10^{2}	4.59×10^{-4}
	^{234}U	4.96×10^{-2}	2.00×10^{2}	2.48×10^{-4}
	^{235}U	2.12×10^{-3}	1.00×10^{2}	2.12×10^{-5}
	^{238}U	3.35×10^{-2}	9.00×10^{1}	3.72×10^{-4}
	^{241}Am	7.10×10^{-4}	2.00×10^{2}	3.55×10^{-6}
Water[b] (Bq/l)	^{60}Co	4.66×10^{-1}	1.00×10^{2}	4.66×10^{-3}
	^{137}Cs	3.23×10^{-1}	2.00×10^{0}	1.62×10^{-1}
	^{234}U	2.18×10^{-1}	7.00×10^{0}	3.11×10^{-2}
	^{235}U	6.51×10^{-3}	8.00×10^{0}	8.14×10^{-3}
	^{238}U	1.08×10^{-1}	8.00×10^{0}	1.35×10^{-2}
	^{241}Am	6.51×10^{-4}	2.00×10^{1}	3.26×10^{-5}
			Sum of Fractions	2.21×10^{-1}
		Terrestrial System Evaluation		
Soil (Bq/g)	^{60}Co	3.66×10^{-4}	3.00×10^{1}	1.22×10^{-5}
	^{137}Cs	1.65×10^{-2}	8.00×10^{-1}	2.06×10^{-2}
	^{234}U	2.09×10^{-2}	2.00×10^{2}	1.05×10^{-4}
	^{235}U	2.32×10^{-3}	1.00×10^{2}	2.32×10^{-5}
	^{238}U	2.27×10^{-2}	6.00×10^{1}	3.78×10^{-4}
	^{241}Am	4.18×10^{-4}	1.00×10^{2}	4.18×10^{-6}
Water (Bq/l)	^{60}Co	4.66×10^{-1}	4.00×10^{4}	1.17×10^{-5}
	^{137}Cs	3.23×10^{-1}	2.00×10^{4}	1.62×10^{-5}
	^{234}U	2.18×10^{-1}	1.00×10^{4}	2.18×10^{-5}
	^{235}U	6.51×10^{-3}	2.00×10^{4}	3.26×10^{-7}
	^{238}U	1.08×10^{-1}	2.00×10^{4}	5.40×10^{-6}
	^{241}Am	6.51×10^{-4}	7.00×10^{3}	9.30×10^{-8}
			Sum of Fractions	2.12×10^{-2}

[a] The radionuclide concentration in the medium that would produce a radiation dose in the organism equal to the dose limit under the conservative assumptions in the model.
[b] Sediment and water samples were assumed to be co-located.